MELTING PROBE TESTS IN THERMAL VACUUM. J. Biele[1], S. Ulamec[1] and A. Parpart[1],
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Introduction: One of the most fascinating aspects of the Europa relevant science is the putative subglacial ocean. To probe this ocean in situ, only melting probes seem to be feasible. The principle of the technology has successfully been proven e.g. in Antarctica [6]. However, a principle difference (at least in the initial penetration) is the low pressure on Europa leading to sublimation rather than melting of the ice layer. Our measurements confirmes an extended theory that includes this effect and demonstrates the feasibility of the method. We how how the transition of sublimation to melting can take place after the "borehole" behind the probe has closed and sufficient pressure has been built up to sustain liquid water.

Theoretical background: In a simple energy balance approximation, neglecting all losses, we can approximate the heat needed to progress a distance l as;

$$\Delta W = Al\rho\,[c_p\,(t_F - t) + L_v] \qquad (1)$$

If the heating power is P, then the melting speed is

$$V = l\,P / \Delta W \qquad (2)$$
$$= P / A\rho\,[c_p\,(t_F - t) + L_v] \qquad (3)$$

where

A is the probe's cross-section (m^2), l is the probes length (m), c_p the specific heat capacity of ice (ranging from 1.5 kJ kg^{-1} K^{-1} to 2.2 kJ kg^{-1} K^{-1}), ρ the density of the ice (~920 kg m^{-3}), L_V the heat of fusion of the ice (~330 kJ kg^{-1}) resp. the heat of sublimation of ice (~2500 kJ kg^{-1}), t_F the melting/sublimation temperature of the ice (K) and t is the local ice temperature (K)

Eq. (3) easily shows that the penetration velocity under sublibmation conditions should be ~7.6 times slower than under melting condition.
An important point here is that the melting velocity scales with the inverse of the cross-sectional area of the probe. Hence the usual design is a cylindrical tube with a large (>10) aspect ratio (length/diameter).

A more sophisticated theory was laid out by [5] and confirmed by [1-4]. Briefly, with an optimal design, about 20% more power has to be expended for a given melting velocity than is suggested by eq. 5. This is because a hole with a slightly bigger cross-section than the probe has to be melted to permit the flow of melt water resp. steam and the conductive heat losses in the surrounding ice have to be accounted for. Great care has to be taken, particularly in cold ice, to ensure that the re-freezing of the ice is slow compared to the melting velocity, in order not to block the probe. Alternative proposals for melting probes foresee heating elements distributed along the length of the probe for that reason.

Experimental setup: Fig. 1 shows the experimental melting probe used here. Its copper melting head can be heated with 200, 400 or 600 W (230V AC) and bears a Pt100 to control the head's temperature. The cylindrical body is hollow yet watertight; the tether is for now externally spooled by a motor, controlled by a force sensor in the tether so the probe is automatically lowered whenever it has sufficiently advanced. An optical counter on the tether wheel senses the depth of the probe.

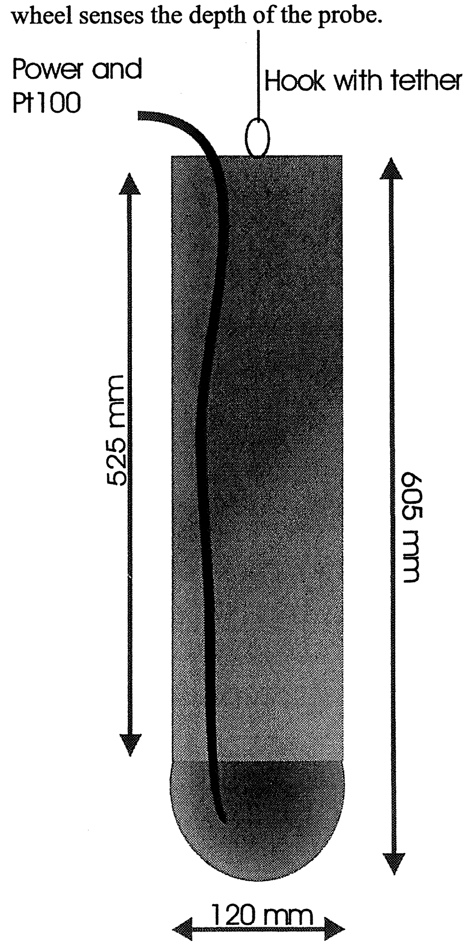

Fig.1: Melting probe (AWI design with refurbishments)

For the thermal vacuum experiments, we use the existing planetary simulation chamber at DLR Cologne Technical data of this chamber is shown in fig.2. The size of the experimental space is as follows: diameter 1.4m, height 1.8m. Cooling system: LN2 (77K)

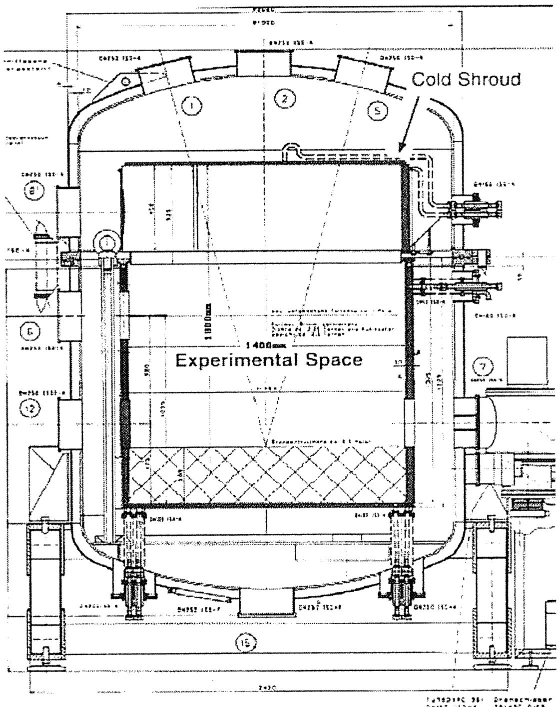

Fig. 2: Thermal vacuum chamber

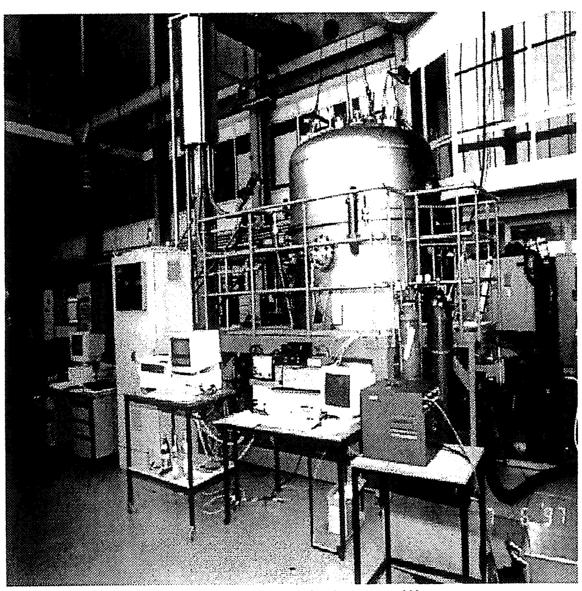

Fig. 3: The Planetary Simulation Facility.

Results: First experiments of melting in ice of -20°C under atmospheric pressure have confirmed that eqn (2) holds,with some 20% losses to be taken into account. In vacuum (ca. 1 mbar, mostly water vapour), however, the penetration velocity after first results appears to be drastically lower. Experiments with different ice temperatures (down to 77 K) and different heater powers (200-600 W) are in progress. Due to freezing of the tether behind the probe once a sufficient depth had been reached, the full process of closing the borehole under vacuum conditions could not yet be fully observed. We plan to refurbish the probe with an internal tether spooler mechanism in the next step.

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